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Implementation of Quality Control Tools in Woven Shirt Mass Customization for Enhancing Product Quality

Rijon SAHA[1], Abdullah Al Rakib SHIKDER[1*], Mahmudul HASAN[1], Jabed Hossen EMON[1], Md Anwar HOSSAIN[1], Md. Abu Bakar SIDDIQUEE[2]

[1]Department of Textile Engineering, Uttara University, Dhaka-1230, Bangladesh

[2]Department of Textile Engineering, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh

*terakib@gmail.com

Article

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ABSTRACT

Mass customization is a dynamic production approach catering to individualized orders. This study addresses the crucial concern of maintaining high-quality standards in woven shirt mass customization. This research delves into defect analysis and quality control, focusing on identifying, categorizing, and mitigating defects in the production process. By meticulously inspecting semi-finished and finished products, defects were recorded systematically on check sheets. Leveraging Pareto analysis, major and minor defects were prioritized, emphasizing critical issues that demand immediate attention. Additionally, a cause-effect diagram was employed to visually map the root causes behind these defects, paving the way for effective preventive measures. Findings highlight the challenges within woven shirt mass customization and underscore the significance of robust quality control. Notably, this research achieved reductions of 6.67% in the cutting section, 16.11% in the sewing section, and 11.11% in the finishing section defects. These outcomes translate into improved product quality and heightened customer satisfaction. This research provides insights for decision-makers and practitioners in the domain, encouraging the integration of comprehensive quality control methods into the production process. By focusing on defect analysis and causal factors, researchers anticipate a positive impact on the industry, resulting in enhanced product quality.

KEYWORDS

mass customization, woven shirts, quality control, defect analysis, customer satisfaction

INTRODUCTION

The ready-made garments sector is a key driver of economic development in developing countries, such as Bangladesh, generating employment and reducing poverty. It's currently transforming with a focus on personalization. Instead of standard sizes, modern practices use real-time customer data for personalized clothing in preferred colours [1]. In response to evolving consumer expectations for enhanced variety and personal choice, both suppliers and retailers have embraced mass production strategies. Yet, amid this profusion of options, a challenge persists: the seamless integration between

manufacturing or design processes is not always achieved [2]. The longstanding dominance of mass production methodologies within the apparel industry has, at times, inadvertently compromised clothing design and fit [3,4].

Presently, the apparel industry stands at the threshold of a significant transformation, spurred by customer-centric business paradigms, interconnections, and streamlined procedures designed to expedite the exchange of information and goods between retailers and manufacturers. In the pursuit of these goals, the adoption of mass customization emerges as a strategic pivot [5-7]. In the age of mass customization, traditional mass-market apparel companies may struggle to meet individual customer requests efficiently at mass-market prices and within realistic timelines [8]. To address this challenge, a strategic shift involves vertically integrated manufacturers partnering with adaptable counterparts, showing promise as a solution for achieving apparel mass customization [9,10].

This research aimed to assess and address defects occurring across various departments within an apparel mass customization unit. Employing a range of quality control tools, the objective was to enable the manufacturing unit to systematically identify and analyze defects that arise during production.

LITERATURE REVIEW

To diversify product portfolios and deliver tailor-made services entities within the apparel market are progressively embracing mass customization as a novel business strategy for both tangible products and intangible services [11]. Tuna in his research stated that the pursuit of mass customization presents its own set of intricate challenges, particularly in terms of organizational structure and type [12]. These challenges wield substantial influence over product performance, quality standards, and adherence to specified delivery schedules. In contemporary market dynamics, consumer expectations have risen across diverse sectors, spurred by the ready availability and convenience of high-calibre goods and services [13].

According to Jiao et al., the concept of mass customization has garnered considerable attention from both academia and industry practitioners and presents an enticing prospect [14]. This approach offers substantial economic advantages by capitalizing on the reuse of product designs and process capabilities, effectively curbing design expenses and amplifying production efficiency.

Fogliatto et al., have identified that interest in mass customization is strong, but progress in quality control for both products and processes has been slow [15]. With increasing product variety and consumer uncertainty, ensuring quality is a significant concern. Based on the study conducted by Kincade et al. adapting quality control tools is essential to maintain the quality of mass-customized goods and services [16].

According to Broekhuizen et al., apparel manufacturers and retailers operate in a multifaceted landscape defined by intense competition and global integration [17]. To excel in this dynamic environment, the industry actively pursues traits of adaptability, efficiency, and precision throughout the processes of forecasting, production, and sales. A customer-centric perspective underscores that the essence of mass customization lies in delivering unparalleled customer value. This is accomplished by designing and delivering products and services that precisely align with individual customer requirements while maintaining an efficiency reminiscent of near-mass production [18,19]. This fusion of tailored solutions and seamless efficiency frequently motivates customers to invest willingly in personalized products that perfectly address their unique needs [20]. Quality control tools are commonly applied in various manufacturing sectors, including textiles and garments [18-20].

However, to the researcher's knowledge, their application in mass customization settings remains limited. Therefore, this study was conducted using a diverse set of quality control tools to identify the root causes of defects in woven shirt production within a mass customization framework. Reducing these defects has a direct impact on enhancing mass customization productivity, benefiting industries at large. Defect reduction not only increases production output but also elevates shirt quality. This, in turn, contributes to heightened customer satisfaction which is a central focus of our research.

EXPERIMENTAL

Materials

This study focuses on a comprehensive investigation conducted at Bit Body Bangladesh Ltd., a mass customization garment factory situated in Ashulia, Dhaka, Bangladesh. The investigation centers on a full-sleeve basic shirt crafted from 100% cotton woven fabric, sourced from Paramount Textiles Ltd., Bangladesh. The sewing process employed 100% spun polyester sewing thread, with a variety of sewing machines such as single needle lock stitch, 3-thread over-lock, 5-thread over-lock, button attaching machines, and flat-lock machines utilized to create the garments.

Methodology

In general terms, mass customization is a consumer-oriented manufacturing technique where the product is manufactured based on the personal requirements of the manufacturers. Here, there is very little scope for the manufacturers to alter the requirements. The sequence of operations that is followed in the mass customization unit where the research was conducted is demonstrated in the following:

Body measurement obtained from the customer using a scanning app
↓
Preparation of the measurement sheet from the data obtained from scanning
↓
Preparation of fabric according to requirement
↓
Fabric cutting (Manually)
↓
Fabric inspection
↓
Sewing
↓
Inspection
↓
Finishing
↓
Final inspection
↓
Packing
↓
Delivered to customer's address

This work was based on the use of quality control tools for defect identification in mass customization. Quality tools are used by different manufacturing organizations to monitor and manage their product quality. However, seven quality tools are available for quality control which can assist an organization in problem-solving and process improvements. Among these tools, some of them have been used previously in the quality management of the apparel industry [18,19]. Three different tools check sheet, a Pareto chart, and lastly cause-effect diagram were used in this research. The methodology is demonstrated in a flow chart below:

Observation of Existing Scenario
↓
Data collection using Check Sheet
↓
Assortment of Major and Minor Defects using Pareto Chart
↓
Root Cause Identification Using Cause-Effect Diagram
↓
Proposed Remedies of the Defects
↓
Implementation of Remedies of the Defects

Observation

The first stage of this research was the observation of the initial quality control system of the mass customization unit. The inputs and outputs of the cutting, sewing, and finishing sections were examined to find out any discrepancies.

Data Collection Using Check Sheet

Before collecting the data by using a check sheet, the observers were trained about the aspects that needed to be observed. There was a team of observers consisting of industrial engineers, academicians, and workers who were able to find out the available defects and list them accordingly on the checklist. The data were collected for several days on the same workers performing the operations for uniformity. The benchmark of the data collection was 180 pieces of garments in each section. The different defects (figure 1) that occurred in the cutting, sewing, and finishing sections during the research have been listed with frequency in a custom-made check sheet. The defects were identified based on academic knowledge and industrial expertise.

Data Analysis Using Pareto Chart

A Pareto chart can also be called a bar diagram which shows the frequencies from the largest to the smallest. This research used this tool to visualize the frequency of defects in each section in descending order from left to right [12,20]. When the defects are arranged in such a way, it becomes easy to see how efforts can be made to improve the condition. The left vertical axis of the chart describes the number of occurrences the right vertical axis denotes the aggregate percentage of the total number of defects.

Root Cause Identification Using Cause-Effect Diagram

This diagram is also popular as a fishbone diagram. This diagram shows the maximum possible causes of the defects. Causes that have been categorized as manpower, process, machine, materials, environment, etc. are mentioned by some of the researchers [12,20]. In this research, this tool was used to find out the root causes of each defect that was found during cutting, sewing, and finishing of woven shirt mass customization. The researchers selected the criteria based on the defects found and by analyzing the root causes responsible for the defects. The causes were then summarized into one cause-effect diagram for each section based on those criteria.

Proposing and Implementing Remedies of the Defects

In this stage identification of problems was found by taking pictures and visual inspection of sewing and finishing lines.

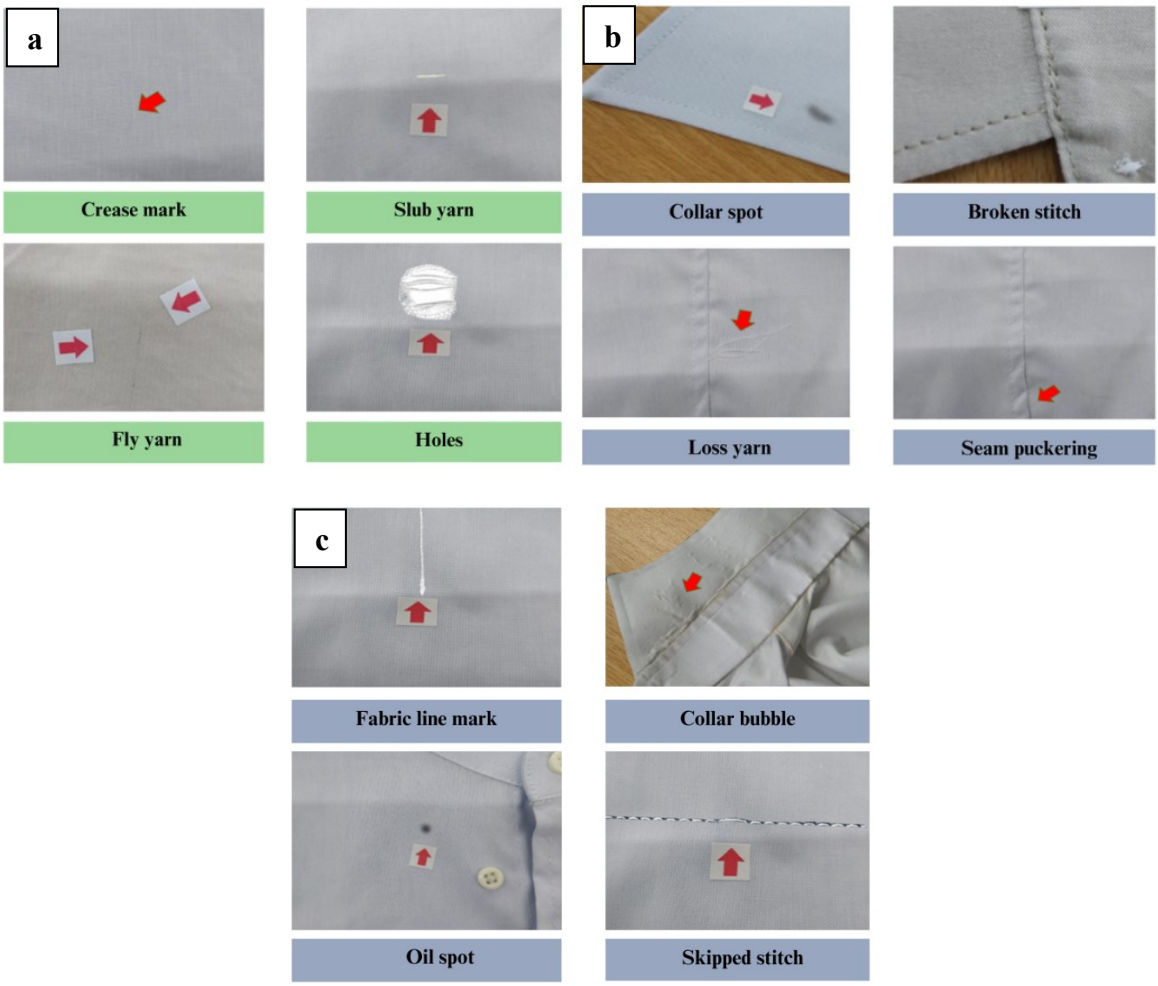

Figure 1. Images of some frequently occurring faults in (a) cutting, (b) sewing, and (c) finishing section

RESULT AND DISCUSSION

Cutting Defects Analysis

The cutting section plays a pivotal role in garment manufacturing, as efficient monitoring and management here can significantly reduce waste. In Figure 2, a Pareto chart displaying defects identified during a quality inspection in the cutting section. Major defects include crease marks, slub yarn, line marks, shade variation, knots, and dirt marks, while minor defects encompass issues like holes, abrasion marks, and print mistakes. This chart not only highlights the various defects but also presents their cumulative percentages. By analyzing this data, researchers prioritized the defects based on their frequency of occurrence. Subsequently, the researcher identified their causes and implemented appropriate remedies.

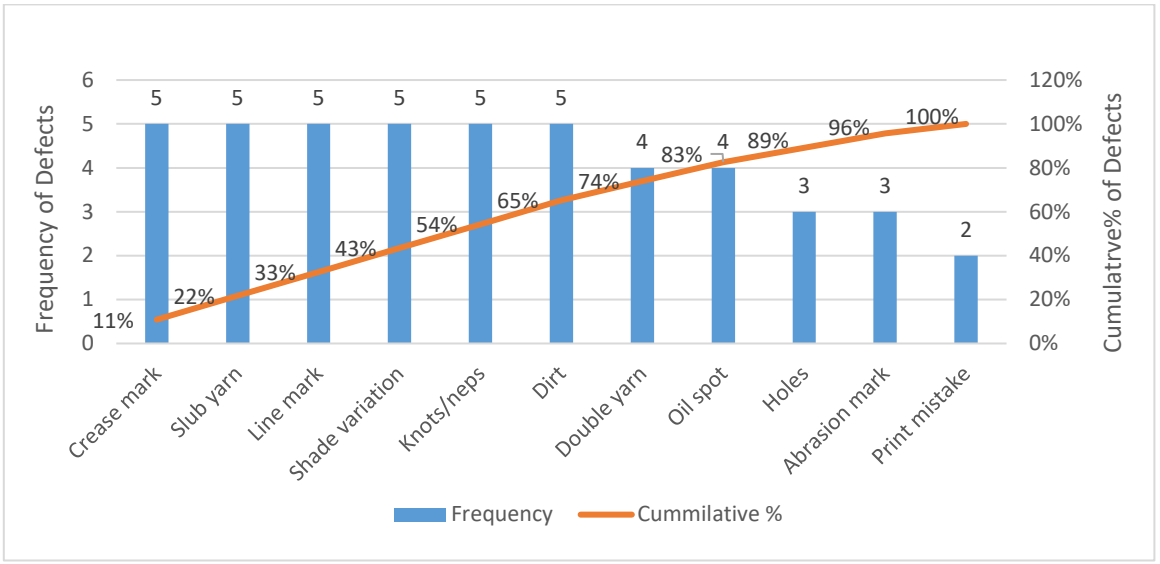

Figure 2. Pareto chart of cutting defects

Cause-Effect Analysis and Corrective Steps for Reduction of Cutting Defects

After identifying the root causes of defects occurring in the cutting section, researchers utilized a cause-effect diagram, commonly known as a fishbone diagram (Figure 3), to illustrate these causes. A team of experts conducted a thorough analysis and categorized the reasons behind these defects into process-related, manpower-related, material-related, machine-related, and environmental factors. This diagram serves as a valuable tool for pinpointing the root causes of these defects and facilitating preventive measures. For example, crease marks often result from improper fabric handling and storage practices. Slub yarn, line marks, and shade variation issues are typically introduced during fabric manufacturing and dyeing processes. Similarly, the causes of other defects observed in the cutting section are detailed in Figure 3.

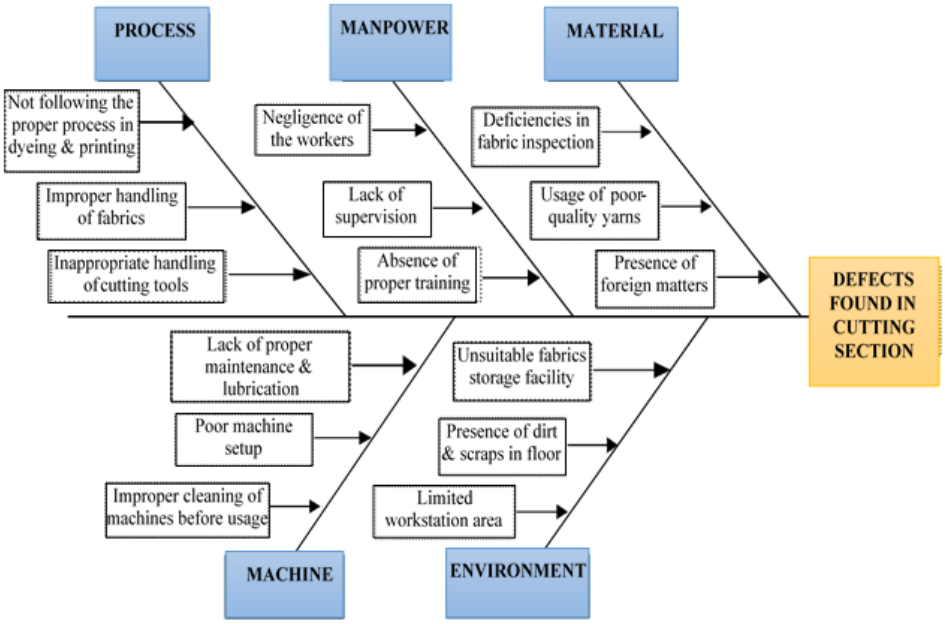

Figure 3. Cause-effect analysis of cutting defects

Table 1. Measures for reducing the cutting defects

Defect Name	Measures Taken
Crease mark	The fabric rolls were stored properly in a rack and transported to the cutting section with proper care.
Slub yarn	The fabric supplier was instructed to use better quality yarn and fabrics were inspected before cutting.
Line mark	Fabrics were inspected using an inspection table and line marks were eliminated.
Shade variation	The fabric supplier was informed and fabrics were inspected using an inspection table.
Knots/neaps	The fabric supplier was instructed to use better quality yarn and fabrics were inspected before cutting.
Dirt	The remained fabric rolls were packaged and stored properly also the fabrics were handled carefully during processing.
Double yarn	The fabric supplier was instructed to use better quality yarn and fabrics were inspected before cutting.
Oil spot	The cutting equipment was cleaned also oil remover was used for rectification.
Holes	Holes were marked using red stickers so they were easily identified and eliminated during cutting.
Abrasion mark	Marks were marked using red stickers so they were easily identified and eliminated during cutting.
Print mistake	Fabrics were marked during the inspection and the mistakes were removed; the fabric supplier was also informed about improving quality.

Effect on Defect Reduction in Cutting Section

Figure 4 illustrates the defect frequency before and after the research was conducted. The causes behind these defects were analyzed through a combination of academic knowledge and brainstorming

sessions involving the research team. Subsequently, effective solutions were implemented in the relevant areas, resulting in a significant reduction in defects within the cutting section. The graph demonstrates a reduction in the frequency of all previously occurring defects. Notably, some defects, such as oil spots and print mistakes, have been eliminated through proper material handling and quality inspection. Additionally, there has been a substantial decrease in the occurrence of defects like crease marks, line marks, and dirt spots. Among these, certain defects were addressed proactively during the raw material purchase phase, while others occurring during the production process, including crease marks, dirt, and oil spots, were successfully reduced by processing the fabrics before usage. The cutting persons were trained in handling the fabric and cutting tools during and after cutting was completed.

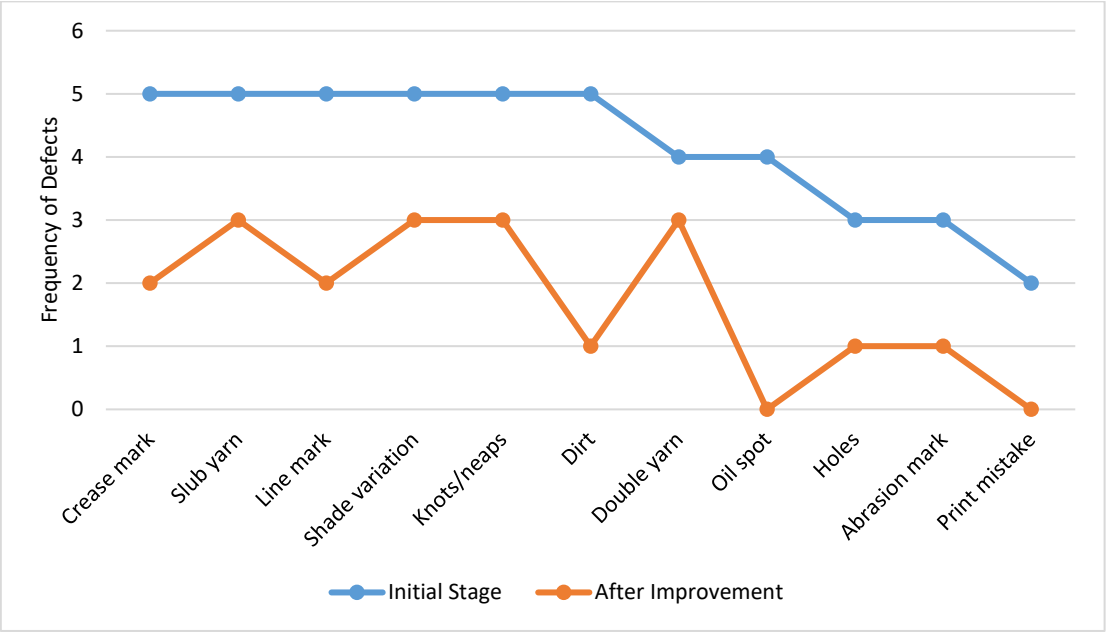

Figure 4. Defect reduction in the cutting section

Sewing Defects Analysis

The sewing section within a garment manufacturing unit is responsible for assembling cut panels according to the garment design. This crucial stage primarily relies on sewing machines, as depicted in Figure 5, which displays the defects identified during an inspection of the sewing section. Figure 5 unmistakably highlights that the most frequently occurring defect in the sewing section is a 'measurement problem.' Additionally, seam puckering and loosely attached buttons stand out as other significant defects. Furthermore, there are noteworthy minor defects, such as incorrect thread tension, needle marks, broken stitches, and skipped stitches, although these occur infrequently. The graph also provides the cumulative percentage of these defects, offering a comprehensive perspective on their contribution.

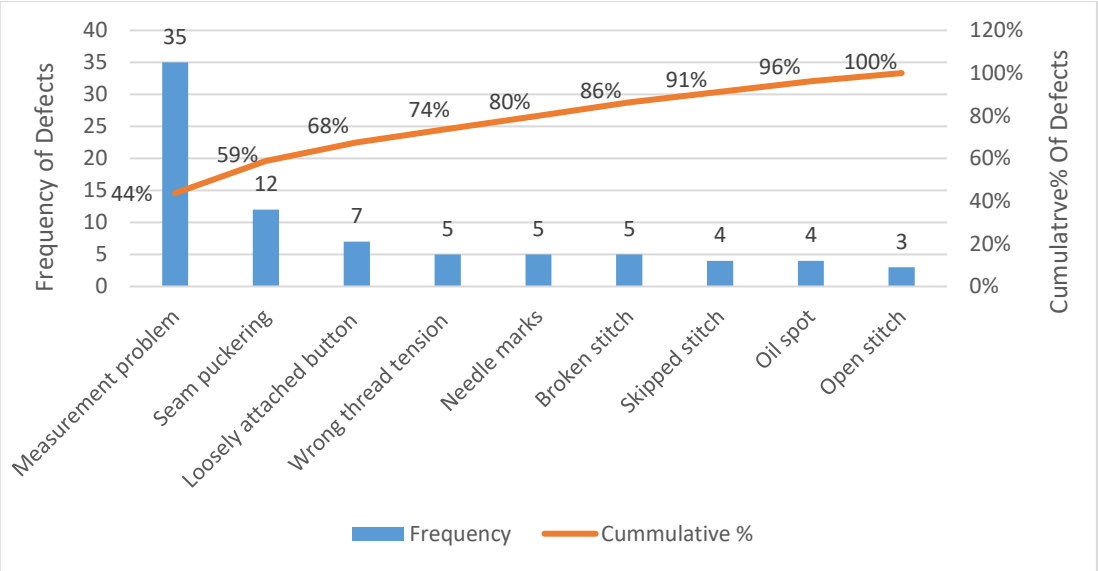

Figure 5. Pareto chart of sewing defects

Cause-Effect Analysis and Corrective Steps for Reduction of Sewing Defects

Figure 5 highlights the 'measurement problem' as the primary defect in the sewing section. This issue is particularly significant in the context of mass customization, where manufacturing must precisely align with individual consumer requirements. In contrast, batch productions typically adhere to standardized size charts. To delve into the causes of these sewing defects, the research team conducted brainstorming sessions, resulting in the identification of causative factors presented in the fishbone diagram illustrated in Figure 6. Notably, some factors like the absence of pannel matching, measurement checking, and in-line inspection contributed to an inability to meet precise measurement requirements, thereby causing the 'measurement problem. This trend extends to other sewing defects mentioned in Figure 5.

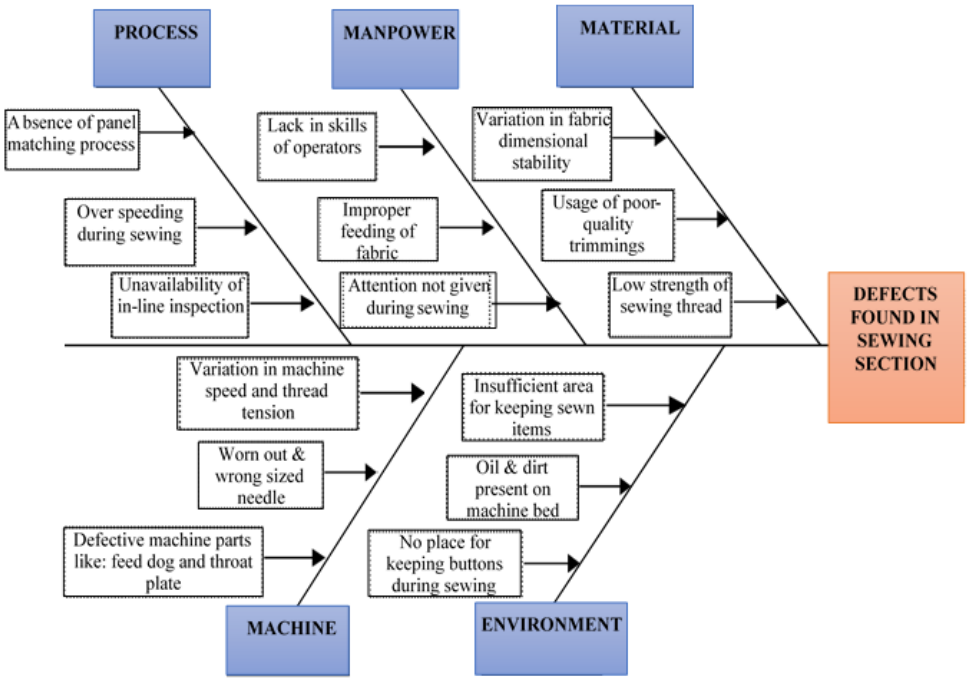

Figure 6. Cause-effect analysis of cutting defects

Table 2. Measures for reducing the sewing defects

Defect Name	Measures Taken
Measurement problem	The cut panels were matched before sewing, inline inspection was introduced during sewing.
Seam puckering	Operators were instructed not to rush, the thread tension was maintained properly and defective parts (Feed dog/ throat plate) were replaced.
Loosely attached button	Workers were trained and inline inspection was included for defect rectification.
Wrong thread tension	Sewing threads of improved quality were used, the sewing thread tension was adjusted accordingly and the defective tensioners were replaced.
Needle marks	Wrong-sized needles were identified and they were replaced by the right ones according to the fabrics used.
Broken stitch	Better quality sewing threads were used, the sewing thread tension was adjusted and worn-out needles were replaced.
Skipped stitch	The workers were supervised and trained, needle height was adjusted and over-speeding of operators was prohibited.
Oil spot	The machines were cleaned properly before starting and after completing production. Lubrication was done under professional supervision.
Open stitch	High-strength sewing threads were used, inline inspection was done for rectification of defects and worn-out machine parts were replaced.

Effect on Defect Reduction in Sewing Section

In the sewing section, the majority of defects occur during the joining of components. Among these defects, one has emerged as particularly prominent: the 'measurement problem.' In the context of mass customization, measurements are obtained directly through a company-operated app, where customer data is processed to guide the cutting process. Before the research, cut panels were not subjected to a thorough inspection, leading to inaccuracies in measurements. Subsequently, after conducting the research, an inspection process post-cutting was implemented, resulting in a significant reduction in the 'measurement problem,' as evidenced in Figure 7. While there remains room for further improvement, researchers acknowledge the need for ongoing research in this area. It's worth noting that all other defects have also witnessed reductions following the research work. The seam puckering was reduced by maintaining proper thread tension during sewing. The attached buttons were checked individually after the process for improved quality.

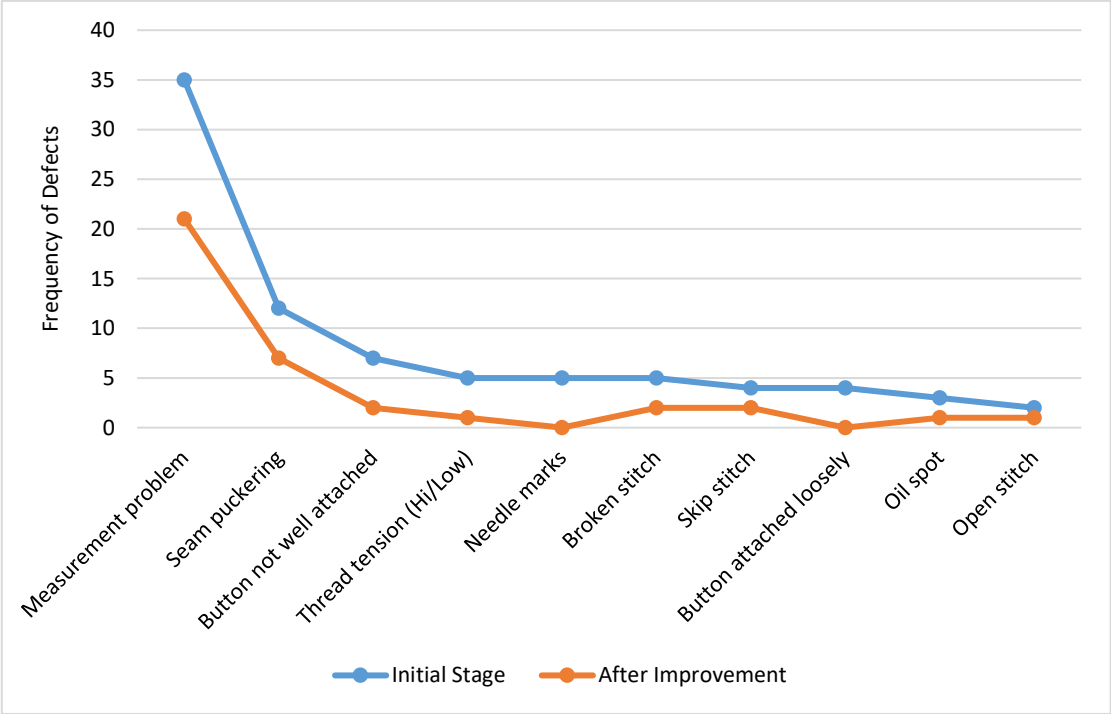

Figure 7. Defect reduction in the sewing section

Finishing Defects Analysis Pareto Chart of Finishing Defects

The finishing section within a garment manufacturing unit plays a pivotal role in ensuring the final quality and appearance of garments before they reach the customer. It serves as the last line of inspection, overseen by the quality control inspector. Figure 8 illustrates the defects identified during inspections in the finishing section. Upon arranging these defects in descending order of occurrence, three major defects emerge as the most frequent: collar bubble, wrong button position, and open

inseam. In addition to these, other issues observed in the finishing section include stripe mismatch, oil spots, seam mismatches, broken stitches, and crease marks, among others. Garments with major defects are routed for immediate rectification, while those with minor defects undergo correction within the finishing section itself.

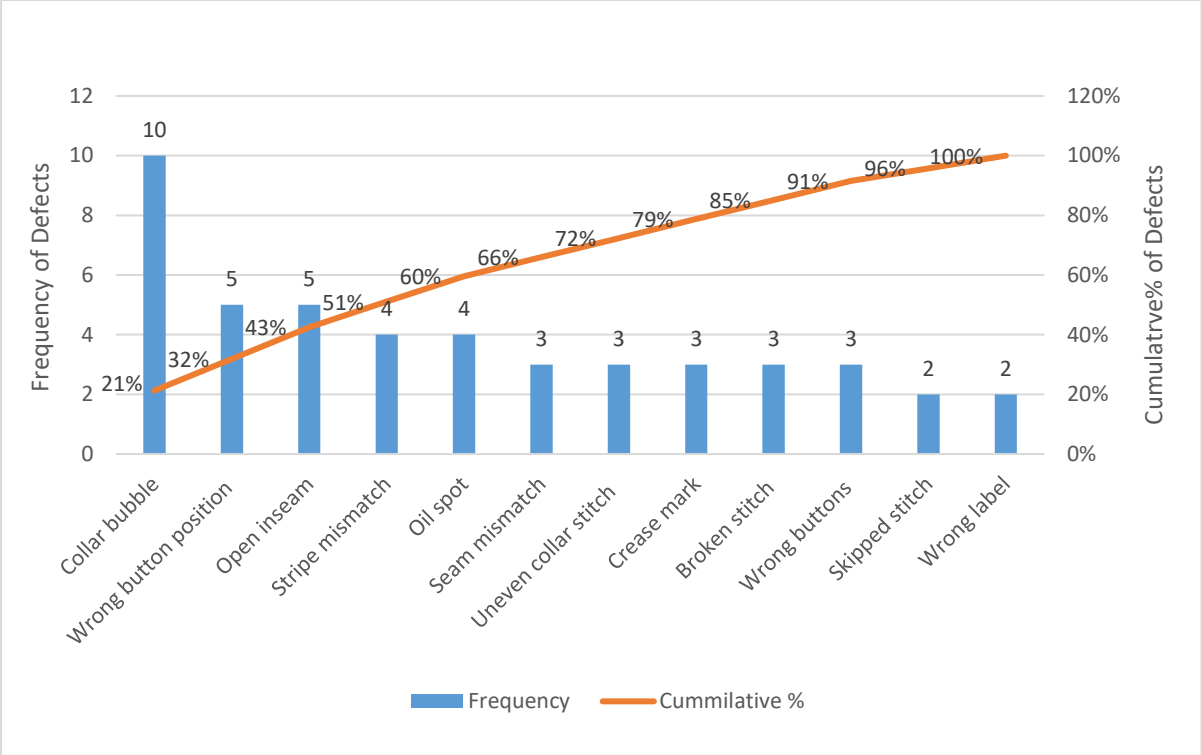

Figure 8. Pareto chart of finishing defects

Cause-Effect Analysis and Corrective Steps for Reduction of Finishing Defects

Figure 9 presents a cause-effect diagram that outlines the root causes of finishing defects. These defects, observed in the finishing section, are closely tied to post-sewing processes, including measurement checks, ironing, label attachment, and packing. The defects arising during these processes undergo final inspection to ensure product quality. The analysis of defect causes involved categorization based on the five factors delineated in Figure 9. For instance, collar bubble defects are attributed to improper interlining fusion, resulting in weak bonding between the interlining and body fabric. Similarly, other defects identified in the finishing section underwent detailed analysis, leading to the identification of their respective causes.

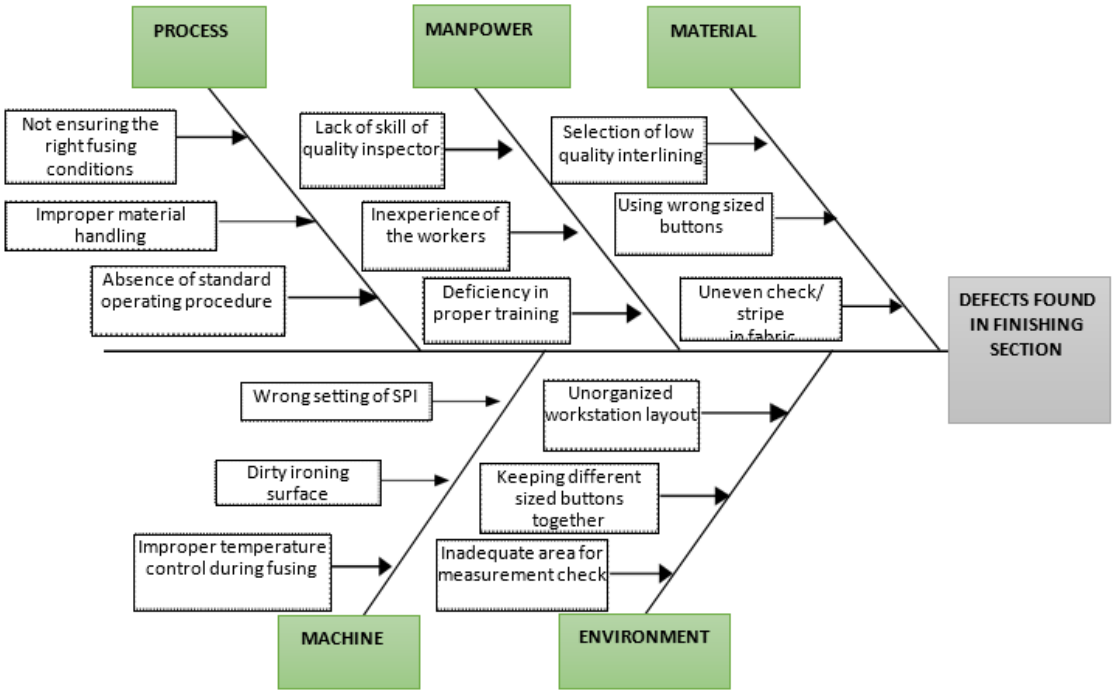

Figure 9. Cause-effect analysis of finishing defects

Table 3. Measures for reducing the finishing defects

Defect name	Measures taken
Collar bubble	Proper fusing temperature was maintained, the operators were trained regarding fusing of the collar, and better quality interlining was used.
Wrong button position	The operators were monitored and instructed properly. They were also requested not to overproduce.
Open inseam	The operators were instructed to inspect each garment during sewing and finishing and rectify if any defects were found.
Stripe mismatch	The printing defects were rectified during fabric inspection, also the in-line inspection was done during production.
Oil spot	Machines were cleaned from time to time and operations were done with caution.
Seam mismatch	The operators were instructed to inspect each garment during sewing and finishing. The final inspection was improved for the identification of these defects.
Uneven collar stitch	The workers were trained and guided by experienced personnel and inspection was done during production.
Crease mark	The ironing operation was monitored and the workers were motivated to remove any crease mark that was present.
Broken stitch	The quality inspectors were instructed to identify of broken stitch. The garments were handled with care during the inspection.
Wrong buttons	The helpers were instructed properly about the product details. The buttons were segregated according to size and style and kept in different containers with proper labelling.

Defect name	Measures taken
Skipped stitch	The garments were inspected properly and any defects found were rectified by sending them back to the sewing section.
Wrong label	The workers in the finishing section were instructed and the labels were checked before using them on the products.

Effect on Defect Reduction in Finishing Section

The finishing section serves as the final stage in garment manufacturing, responsible for ensuring that garments are presented in their best possible condition to the buyer. It involves a thorough inspection to identify and rectify any defects before packaging. Before the research, inspections occasionally revealed defects in finished garments. Major issues included collar bubbles, wrong button positions, and open inseams. These defects were primarily attributed to improper fusing conditions and lapses in operator concentration. Interlinings of better quality were used during the research. Also during the fusing of interlining with body fabric, the proper fusing conditions (time, pressure, and temperature) were maintained by providing proper training to the operators. The buttons were cross-checked before attaching to avoid the wrong button attachment. By addressing such shortcomings, it is very significant that successfully reduced the frequency of defects, as depicted in Figure 10. Notably, the elimination of defects such as uneven collar stitches and incorrectly attached buttons.

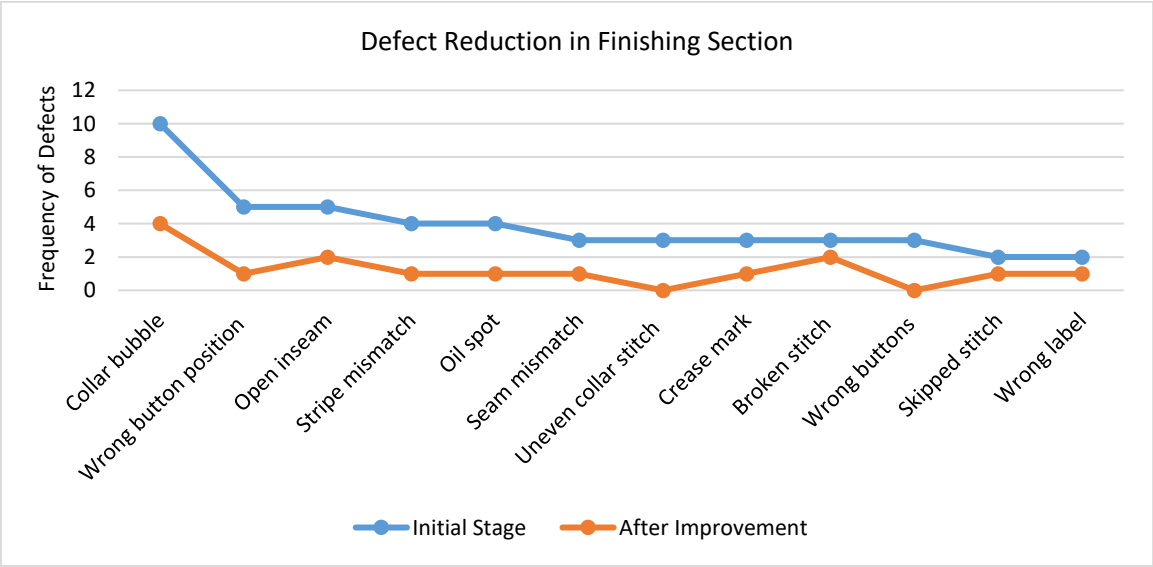

Figure 10. Defect reduction in the finishing section

Total Improvement in Quality

A total of 180 items were inspected in each section, and the number of defective items in the cutting, sewing, and finishing sections was recorded. Subsequently, another round of 180 items inspection was

carried out after implementing the remedies for the problems identified, resulting in a notable reduction in the number of defective items. This reflects an overall enhancement in the quality of the woven shirt mass customization. To provide a comparative view, the percentages of defective items are presented in Figure 11. In the cutting section, there was a reduction of approximately 6.67% in defective items before and after the research. The sewing section exhibited the most substantial improvement, with a reduction of approximately 16.11%, showcasing the highest reduction among the three sections and indicating significant enhancement in overall quality. Furthermore, the finishing section also saw commendable progress, with a reduction of approximately 11.11% in defect percentages. This reduction in the defect percentage indicates that quality improvement has significantly occurred in the sewing section where the measurement problem was the major problem. In mass customization, proper measurement is the key element for achieving customer satisfaction. The finishing section also has seen progress in quality improvement. The majority of the faults in garment manufacturing are found in the finishing section during the inspection. In this research, defects in this section were removed by following proper processes and an inspection system.

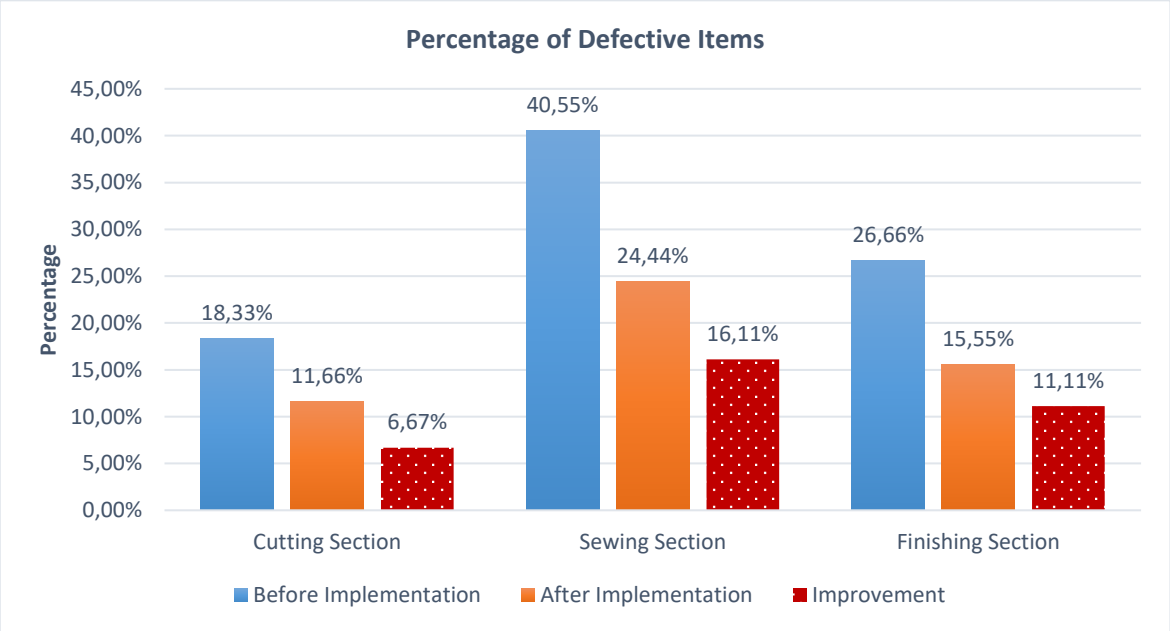

Figure 11. Defect reduction in the total process

CONCLUSION

In the realm of readymade garment manufacturing, particularly in countries such as Bangladesh, the emergence of mass customization is a promising and transformative concept. As the demand for personalized garments continues to surge, mass customization offers substantial potential for the nation's garment industry. This study has centred on the identification and improvement of quality

problems in woven shirt manufacturing within the context of mass customization. Notably, the researcher's efforts have yielded significant quality enhancements in defect reduction of 6.67% in the cutting section, 16.11% in sewing, and 11.11% in finishing. The target of this research has been the enhancement of product quality by studying the existing scenario of a Bangladeshi mass customization unit. To achieve this goal, quality control tools including meticulous check sheets, Pareto charts, and cause-effect diagrams were employed.

Though there were some mentionable limitations faced during this study. The sample size considered for this study was somewhat small. The raw materials used (i.e. fabrics and sewing threads) were specified. Usage of different materials may have a different impact on the outcome of such research. This research was done focusing on a newly established mass customization unit, where standard operating procedures followed in garment manufacturing were absent. Also, this study focused particularly on woven shirt mass customization which can also be considered as a limitation.

Regardless of the limitations, the insights derived from this research provide woven garment manufacturers with actionable strategies to proactively address and prevent defects, thereby enhancing the overall quality of mass-customized shirts. The research findings can be valuable for further studies in mass customization of other garment products as mass customization is shifting towards the production of high-end garments like suits, blazers, etc.

Author contributions

Conceptualization – Saha R; methodology – Saha R and Siddiquee MAB; formal analysis – Saha R and Hasan M; investigation – Hasan M; resources – Hasan M; writing-original draft preparation – Shikder AAR; writing-review and editing – Shikder AAR, Emon JH, and Hossain MA; visualization – Shikder AAR and Emon JH; supervision – Siddiquee MAB and Saha R. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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